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JOHN F. DASHIELL
UNIVERSITY OF NORTH CAROLINA

The Pupillary Response Conditioned to Subliminal Auditory Stimuli

By

LYNN E. BAKER
UNIVERSITY OF WISCONSIN

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CONTENTS

SECTION I. INTRODUCTION

If it is possible to effect a conditioned connection between a stimulus that is below the conscious limen and a response that is similarly non-conscious, such a connection is of definite importance to the theory of learning. To demonstrate that in a conscious subject the conscious processes are not a necessary part of all associative learning has decided implications for any problem in which conscious processes are to be considered, as well as for the theory of learning in general.

On the side of conditioned response theory in particular there are also many implications of such a datum. In the first place, such conditioning might be considered to give the basis for a classification of "levels" of learning. It might be argued, for instance, that the typical picture of conditioning is never given in conscious human subjects because conscious processes intervene to distort the basic picture. In this case such conditioning as we are here considering might be expected to give a closer approximation of the "basic" conditioning process.

Considered in another light the evidence might be taken to indicate that the conditioned response *is* the basic mechanism of learning when conscious processes are not involved, but that with the inclusion of conscious factors another mechanism or mechanisms must be sought.

The present research is directed toward a consideration of this problem. The experiments were so devised that a subliminal auditory stimulus was associated, by the conditioned response method, with change in pupillary diameter. The limen below which the conditioned stimulus (hereinafter called *CS*) was applied is defined as *that auditory intensity below which the subject is unable to be consciously aware of the occurrence of the stimulus.* Since our subjects, in addition to being unaware of the occurrence of *CS*, were also unaware of the occurrence of the response conditioned, the study demonstrates the fact that a conditioned connection may be established between a non-conscious stimulus and a non-conscious response.

Similar problems have been studied by a few other experimenters. Newhall and Sears (13) attempted to condition finger withdrawal to stimuli just above, just at, and just below the psychophysical threshold. Their experiment was conducted for the purpose of testing Hamel's (8) thesis that the conditioned response is always dependent upon conscious processes. Their results led them to conclude that the conditionability of stimuli below the psychophysical threshold seemed certain; but that whether or not conditioning was possible when the subject was not conscious of the occurrence of *CS* was still in doubt. Our own experiment differs from that of Newhall and Sears in that the response conditioned was a non-voluntary one, and the limen below which *CS* was presented was not the psychophysical threshold but the absolute limen of awareness of the stimulus.

Cason and Katcher (4) reported that the responses involved in respiration and leg-tension were not conditioned to subliminal electrical stimulation, and the limen used in their study was the same as that which we have used in the present experiments. Silverman and Baker (14), however, did find suggestive evidence of conditioning in three, and reconditioning in two, out of twelve subjects when the eye-lid response was used. Partial corroboration of their results has been claimed by Neet (12). A fact that is worthy of note here is that the Silverman and Baker study showed no evidence of conditioning when the response used was one which involved a gross voluntary muscle group; but when the eye-lid response was used there appeared some evidence for conditioning. Unfortunately, when an electrical stimulus is used it is impossible to define the limen very precisely. It is well known that the use of the auditory modality is not subject to the same objection.

In addition to investigating the possibility of establishing a connection between a subliminal stimulus and the pupillary response, we have conducted further experiments on (a) the course of acquisition of the conditioned connection, (b) comparison between conditioning to supraliminal and to subliminal intensities of *CS*, (c) the specificity and lower limits of *CS* intensities, (d) experimental extinction, (e) unconditioning, and (f) retention of the conditioned connection.

Our data on the course of conditioning and unconditioning were gathered by the delayed conditioned response method in which *CS* precedes and overlaps *US*. This method is admirably adapted to the study of such functions, since the occurrence of an "anticipatory" response gives immediate evidence of the first occurrence of the conditioned response. All data, from a total of thirty-four subjects, show that a conditioned connection is formed in a single training combination when *CS* is subliminal. This result is of special interest in view of the suggestion made in this direction by such authors as Guthrie (7). Our data further show that the conditioned pupillary response exhibits a change in form with additional training.

The results on experimental extinction in the present study show that there is little or none of this type of adaptation except under certain conditions. Our data on specificity and retention of the conditioned response are also at variance with the Pavlovian description of conditioning.

In the next two sections of this paper we shall first describe the apparatus and general procedure. In subsequent separate sections we shall describe the procedures used and the results obtained in each of the separate experiments. The final sections will be devoted to a discussion and interpretation of results, and to a summary of the entire research.

SECTION II. APPARATUS

The auditory stimulus was administered to *S* by means of a pair of ordinary head-phones connected to an audiometer. The modifications of this instrument which were necessary for our purposes have been described in a previous paper (1).

Observation and measurement of the pupil was accomplished by means of a pupillometer.[1] This instrument had a magnifying power of 16 diameters. Measurements of the responses were made with stadia-hairs in *E*'s end of the pupillometer. These

[1] The instrument was designed and built with the collaboration of Mr. E. Romare of the School of Engineering of the University of Wisconsin. It employs many features adapted and modified from the descriptions of similar apparatus by Weiler (16) and by Ferree and Rand (6). It is substantially the same as that used by Cason (3), but is not identical in mechanical detail.

hairs were seen as superimposed vertically upon the iris of *S*, and were moved together and apart by means of a two-way micrometer screw. After a certain amount of skill had been acquired through practice, *E* found very little difficulty in keeping the stadia-hairs tangential to the margins of *S*'s pupil.

Fluctuations in pupillary diameter, as well as the incidence of the conditioned and unconditioned stimuli, were recorded on a wax-paper kymograph. The stylus for recording pupillary variations was actuated by means of a mechanical system which operated from a reel on the stadia-hair control. The styli for recording time and the occurrence of the various stimuli were electro-magnetically operated.

The unconditioned stimulus (hereinafter called *US*) for changes in pupillary diameter was variation in light intensity. Light for this purpose was furnished by a 60-watt electric lamp. Illumination of *S*'s eye could be varied between 3.5 and 20 foot-candles by means of a rheostat introduced into the current-supply of the lamp.[2]

E and *S* were separated from each other by means of a 4 x 5 foot black screen through which extended the objective end of the pupillometer. *S* sat in a straight-backed chair with his head held firmly in place by means of a head-rest and an adjustable chin-support. A 5½ x 4¼ inch milk-glass window in the screen was situated at about the level of *S*'s chin and admitted to him the light which served as *US*.

With his head in place in the apparatus, *S* was able to see a reflection of his own eye in the first lens of the pupillometer. Since this mirroring surface was a convex one, the reflection of *S*'s iris was small and made a satisfactory fixation object. It was about 7½ inches removed from *S*'s eye and was in such a position as to require him to keep his eye entirely open without allowing the lid to droop and hinder *E*'s vision.

[2] In this single particular, *i.e.*, the control of light intensities at the eye of *S*, is our apparatus less accurate than that used by other experimenters (**3**, **11**, **15**). While these others were able to keep chromatic values constant, the same control was not possible with our equipment. Thus, the light furnished at the 3.5 intensity was noticeably redder than that furnished at higher intensities. However, we were not able to observe that this made any systematic difference in our results.

SECTION III. GENERAL PROCEDURE

In the training of pupillary constriction, *US* was an increase in light intensity from a base of 3.5 foot-candles to a maximum intensity of 20.0 foot-candles. In the training of dilation, *US* was a decrease in light intensity from a base of 20.0 to an intensity of 3.5 foot-candles. In the testing procedures it was found advisable to use a light intensity somewhere between these extremes, and 8.2 foot-candles was arbitrarily chosen as an intensity which allowed change of the pupil in either direction. All tests were run with the light at this middle intensity.

On the first experience of each *S* in the experimental situation the conscious threshold-for-the-stimulus was carefully determined by the same method as that used by the present author in a previous study (1). This method consisted in presenting stimuli over a wide range of intensities, and so discovering the intensity-level below which *S* was unable to perceive consciously the occurrence of the stimulus. The limen so determined is a singularly stable one which exhibits almost no day-to-day fluctuations. In the following outlines of procedure, "Limen determination" refers to this particular method.

With each *S* only a brief examination was made on sessions after the first to determine whether the limen had shifted. This was done simply by increasing and decreasing gradually the intensity of the stimulus and asking *S* to report the point at which he was just able to hear the sound. *S*'s performance in this case was then compared with that in the initial test and adjustment was made when indicated. This entire process will be referred to in the following outlines of procedure as "Checking the limen."

In the determination of the limen *S*'s surroundings duplicated exactly the conditions which would later appear in the conditioning procedure. His posture was the same, the sounds made by the Harvard clock and the time-markers were the same, and the hum of the motor used to drive the audiometer brush was the same. The only observable difference was that in the determination of the limen *S* was attending to the sound in the head-phones,

while in the conditioning procedure his attention was directed toward keeping his eye fixated in the proper fashion. Because of this difference his limen as influenced by the attention factor would probably be slightly higher in the conditioning situation.

During the conduct of the conditioning experiments frequent rests were given *S* in order to relieve fatigue. We had, however, found in preliminary investigations that it was possible to have him fixate for much longer periods of time than previous experimenters had thought advisable. We were therefore able to take continuous records throughout as many as six consecutive training combinations without undue strain upon *S*.

CS was presented for 19 seconds, and *US* overlapped the subliminal sound for the last 10 seconds of the 19-second period. Thus the procedure for a single training combination was as follows:

1. *CS* presented, continued alone for 9 seconds.

2. *US* presented 9 seconds after start of *CS;* both stimuli continued together for 10 seconds.

3. Both stimuli stopped 19 seconds after the beginning of the presentation.

In the testing procedures, *CS* was presented for 15 sec. without reinforcement by *US*. In both the training and the testing procedures the intervals between applications were irregularly varied between 10 and 30 sec. according to a chance distribution. Continuous records were taken of the behavior of the pupil during and between the applications of the various stimuli.[3]

[3] The following is a list of the abbreviations used in this paper:

CS—conditioned stimulus (sound).

US—unconditioned, or original, stimulus (light change).

Test—presentation of *CS* alone, unreinforced by *US*, for 15 sec. The word *Test* is followed in the outlines by a numerical indication of the intensity of *CS* in each case. Thus, *Test-sub-2* indicates that *CS* was at an intensity two audiometer-units below *S*'s conscious threshold. Likewise, *Test-0* indicates that the intensity of *CS* was zero, *Test-supra-2* indicates a *CS* intensity two units above the limen, and *Test at limen* indicates a *CS* intensity that was just at the limen.

Train—*CS* and *US* presented in combination to produce the learning. This symbol is also always accompanied by a numerical indication of the intensity of *CS*.

S—subject.

E—experimenter.

SECTION IV. CONDITIONING THE RESPONSE

Problem. To condition a pupillary response to a subliminal auditory stimulus.

Procedure. Session 1—Determination of the limen.

Session 2—(a) Checking the limen. (b) One of the following procedures was used for each *S*. It will be noted that the two procedures reverse the order of periods in order to control any possible effect of that factor on the results.

Group A	Group B
1. *Test-0* (control test-before-training)	1. *Test-sub-2* (control test-before-training)
2. *Test-sub-2* (control test-before-training)	2. *Test-0* (control test-before-training)
3. *Test-0* (control test-before-training)	3. *Test-sub-2* (control test-before-training)
4. *Train-sub-2* (conditioning)	4. *Train-0* (conditioning control)
5. *Test-0* (control test)	5. *Test-sub-2* (control test)
6. *Test-sub-2* (test-for-conditioning)	6. *Test-0* (conditioning control)
7. *Train-0* (conditioning control)	7. *Train-sub-2* (conditioning)
8. *Test-0* (conditioning control)	8. *Test-sub-2* (conditioning test)
9. *Test-sub-2* (conditioning test)	9. *Test-0* (conditioning control)
10. *Test-0* (conditioning control)	10. *Test-sub-2* (conditioning test)

*S*s were divided into two groups, one group of four using the procedure outlined in column A, the other group of three using that of column B. For Group A conditioned constriction was the experimental desideratum, while for Group B conditioned dilation was sought.

The testing and training with *CS* at 0 intensity was for control purposes. Since *CS* was a stimulus of so low an intensity as to be unperceived by *S*, extreme care had to be taken to control all incidental stimuli. In order to preclude the possibility that the conditioning might be attributable to such stimuli, this conditioning control was used. If conditioning appears with *CS* at the intensity *sub-2*, but does not appear with *CS* at 0 intensity, then it follows that such conditioning cannot be attributed to any other *CS* than the one designated.

It was thought advisable to attempt a further control along these lines. Accordingly, the entire conditioned response procedure, consisting of control test, training period, and final test-

for-conditioning, was carried out on two *S*s with the audiometer entirely disconnected from the ear-phones. These two *S*s were given 280 training combinations in this fashion. When tested after such training, neither *S* showed the slightest effect of conditioning. It is apparent that if whatever conditioning we obtained were accountable to some such uncontrolled sound as the closing of a switch, a characteristic movement of E, etc., the same conditioning would have evidenced itself in this control procedure. The fact that no such conditioning occurred seems to us to be positive proof that there were no such incidental stimuli effective in the situation.

Results. The results of this procedure are given in Table I. This table represents the average height of the response-curve for all *S*s at intervals of 1 sec., and the A D. of that average. To establish a base-line, the height of the curve at the first instant

TABLE I

CONTROL AND TESTS FOR CONDITIONING WITH CONSTRICTION AND DILATION RESPONSES

Seconds	Pupillary change in mm. at 1 sec. intervals												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Control test (before training)													
Means	0.0	—0.2	—0.2	—0.1	0.0	0.0	0.0	—0.1	—0.1	—0.1	0.1	0.1	0.0
A.D.s	0.0	0.3	0.3	0.6	0.7	0.5	0.4	0.4	0.4	0.5	0.5	0.7	0.4
Test for conditioned constriction													
Means	0.0	—0.8	—1.5	—2.3	—2.7	—3.1	—2.7	—2.7	—2.7	—2.9	—2.9	—2.8	—3.3
A.D.s	0.0	0.5	0.8	0.8	1.1	1.0	0.9	0.8	0.9	0.8	0.8	0.8	1.0
Test for conditioned dilation													
Means	0.0	0.5	0.8	1.7	2.1	2.3	2.5	2.1	2.2	2.3	2.3	2.5	2.4
A.D.s	0.0	0.6	0.5	0.7	1.0	1.1	0.9	1.0	1.0	0.8	0.9	0.9	1.1

Seconds	Pupillary change in mm. at 1 sec. intervals											
	13	14	15	16	17	18	19	20	21	22	23	24
Control test (before training)												
Means	—0.2	—0.3	0.2	0.0	0.0	—0.2	—0.1	0.0	0.0	0.1	0.0	0.0
A.D.s	0.7	0.8	0.5	0.6	0.7	0.4	0.3	0.7	0.4	0.7	0.6	0.4
Test for conditioned constriction												
Means	—2.4	—2.4	—3.2	—1.9	—1.2	—0.6	—0.2	0.3	0.6	0.2	0.2	0.3
A.D.s	1.2	1.1	1.0	1.0	1.1	1.1	1.0	0.9	0.8	0.8	0.7	0.5
Test for conditioned dilation												
Means	2.5	2.6	2.5	1.7	0.5	—0.3	—0.6	—0.4	—0.4	0.0	—0.3	—0.3
A.D.s	0.9	1.2	0.9	0.9	0.8	0.7	0.7	0.7	0.5	0.6	0.6	0.4

of the period was arbitrarily taken as 0. The height of the line above or below this point was then measured at one-second intervals throughout the period, and these measures were then averaged for all *S*s for each progressive second to give the figures presented in the table. In other words, the table represents a summary such as would be expressed in a composite curve. Such a curve, drawn from these data, is presented in Fig. 1. The results of the controls in which *CS* intensity was zero are not included in either the table or the figure. Without any exception they showed absolutely no evidence of conditioning.

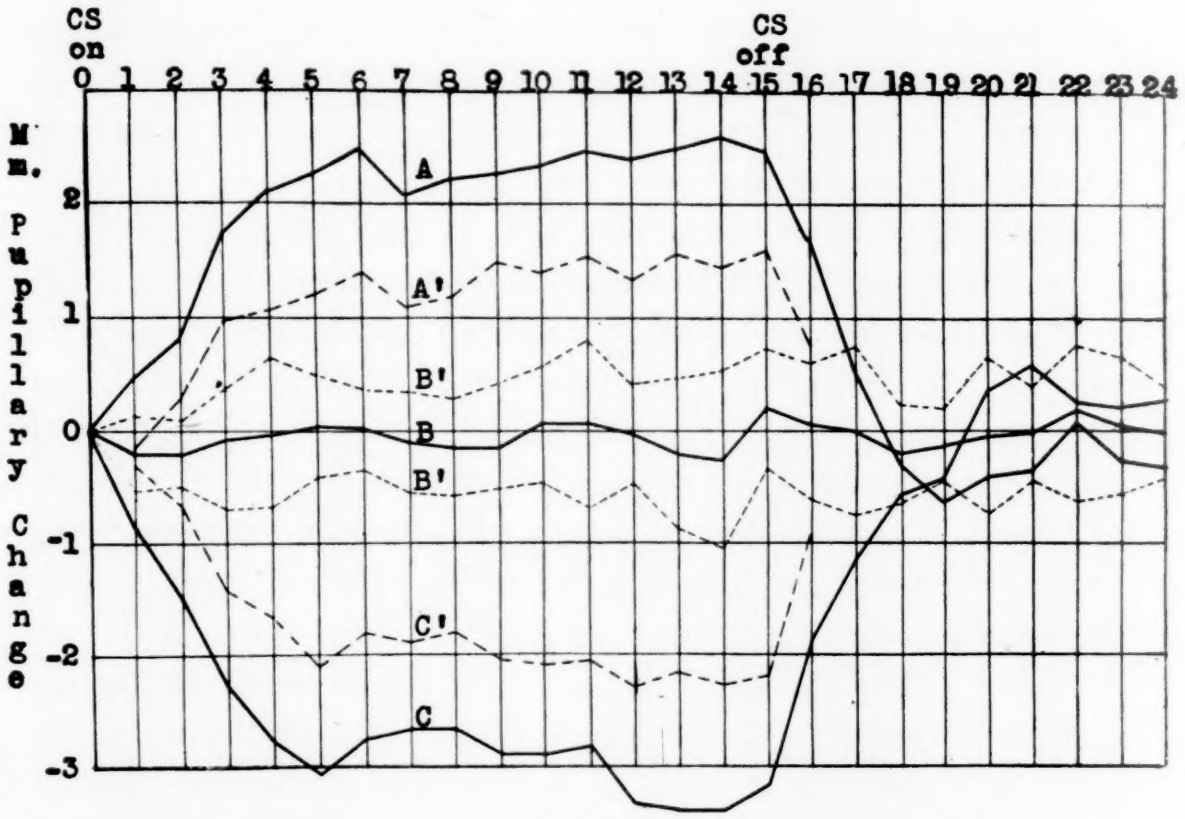

FIG. 1. Tests for pupillary response conditioned to subliminal auditory stimulus. B—Control test; B′—A.D. of B. A—Test for conditioned dilation; A′—A.D. of A. C—Test for conditioned constriction; C′—A.D. of C.

Conclusions. It is immediately apparent that these data show definite evidence of conditioning. Whereas in the control test-before-conditioning (curve B, Fig. 1) the maximum mean change in the direction of constriction was 0.26 mm. at the pupil, in the test after training of contraction (curve C, Fig. 1) the maximum mean change in pupillary diameter was 3.4 mm. Com-

parison of curves A and B, Fig. 1, gives essentially the same conclusion concerning conditioned dilation. Furthermore, these differences in means are several times the A.D.s of the measures, so that at no time after the second sec. of the test do the A.D.s overlap.

SECTION V. THE COURSE OF CONDITIONING

Problem. To describe the course of acquisition of the conditioned pupillary response.

Procedure. Since we presented *CS* nine seconds before the presentation of *US*, and since this method resulted in the appearance of an anticipatory response, it was possible to observe and measure the formation of the conditioned response from combination to combination.

Accordingly, all the data from 16 *S*s, 8 of whom were trained in the direction of dilation and 8 in the direction of constriction, were grouped by direction of response and ordinal number of training combinations. The heights of the curves were then measured and averaged at one-second intervals throughout the training combination. Thus the average height of the response-curves of the first training combination was compared with similar measures of the second, third, fourth, etc., training combinations.

Results. The average heights of the response-curves for each successive second of the separate training combinations are presented in Table II. In Fig. 2 is presented a graphic summary of the results given in the table. This figure presents composite curves for the comparison of anticipatory responses of the first, second, and third training combinations in which dilation was the response conditioned. In addition to these the same anticipatory responses are shown for conditioned constriction, and also the data for training combinations 4 and 73. The curve showing the anticipatory response of the 73rd training combination (curve 73C) differs from the others in that it is drawn from a single response of a single *S*. All others are composite curves from all *S*s.

TABLE II

COURSE OF DEVELOPMENT OF CONDITIONED PUPILLARY RESPONSE

Progressive Seconds During the Training Combinations

	CS on — Period of delay									*US* on — Period of paired presentation										Both st. off
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Comb. # 1																				
Contraction	0.0	—0.4	0.0	—0.2	—0.1	—0.1	—0.2	—0.1	—0.4	—0.2	—2.5	—4.6	—6.6	—8.7	—7.2	—7.2	—6.3	—6.6	—6.7	—6.6
Dilation	0.0	0.3	—0.2	—0.1	0.0	—0.2	0.0	—0.1	—0.1	—0.1	1.7	2.1	3.3	4.6	5.3	6.0	6.3	5.9	6.1	6.2
Comb. # 2																				
Contraction	0.0	—1.1	—2.2	—1.1	—1.5	—3.3	—2.7	—1.3	—2.9	—1.3	—2.9	—4.9	—5.7	—7.4	—8.2	—8.2	—7.7	—7.9	—8.2	—7.8
Dilation	0.0	0.8	1.2	0.6	1.9	2.4	1.3	1.5	1.8	1.6	2.3	2.7	3.2	3.9	4.7	5.3	5.8	6.5	6.3	6.0
Comb. # 3																				
Contraction	0.0	—0.4	—2.7	—4.3	—3.7	—3.9	—4.7	—4.0	—4.4	—4.6	—5.3	—8.4	—8.8	—8.8	—7.9	—8.4	—8.1	—8.1	—8.1	—8.6
Dilation	0.0	1.4	2.5	2.5	3.4	3.7	4.0	4.1	3.7	3.5	3.9	4.4	4.9	5.4	5.4	5.9	6.3	6.4	6.3	6.0
Comb. # 4																				
Contraction	0.0	—0.8	—2.5	—4.6	—4.5	—3.8	—4.3	—4.9	—4.6	—4.3	—4.3	—6.7	—8.4	—9.0	—10.0	—8.6	—8.1	—7.8	—6.9	—7.0
Dilation	0.0	1.3	2.2	2.9	3.8	3.5	3.9	3.6	3.8	4.1	4.4	4.9	5.0	5.7	6.1	6.3	6.6	6.5	6.0	6.2
Comb. # 5																				
Contraction	0.0	—0.6	—1.9	—4.8	—3.9	—4.0	—4.2	—4.5	—5.4	—4.7	—5.1	—5.4	—8.3	—9.5	—8.6	—8.6	—9.0	—9.1	—8.6	—8.6
Dilation	0.0	1.0	2.5	2.7	3.8	3.4	3.7	3.9	4.0	3.5	3.6	4.5	5.1	5.6	5.8	6.2	6.6	5.9	6.1	6.2
Comb. # 6																				
Contraction	0.0	—1.0	—2.7	—4.4	—5.7	—4.4	—4.9	—4.7	—4.8	—4.1	—5.7	—6.1	—8.0	—8.3	—8.8	—8.2	—8.1	—8.7	—8.3	—7.8
Dilation	0.0	1.2	2.7	3.0	3.3	3.9	5.1	3.6	3.9	3.7	4.1	4.3	5.1	4.9	5.2	5.8	6.3	6.5	6.2	6.2
Comb. # 10																				
Contraction	0.0	—0.5	—2.3	—4.4	—4.8	—3.7	—4.1	—4.2	—5.1	—4.0	—4.3	—5.4	—7.7	—6.7	—7.9	—8.6	—8.9	—8.3	—8.0	—8.4
Dilation	0.0	1.1	2.6	2.9	3.5	3.4	3.9	4.0	3.7	3.7	4.3	4.8	4.9	5.3	5.5	5.9	6.0	5.9	6.3	6.0
Comb. # 20																				
Contraction	0.0	—0.9	—3.4	—4.1	—4.7	—4.3	—4.9	—4.1	—4.5	—4.3	—4.9	—5.9	—8.7	—8.4	—7.8	—8.4	—8.4	—8.2	—7.8	—8.4
Dilation	0.0	1.3	2.1	2.6	3.6	3.4	3.6	3.7	3.9	3.9	4.0	4.9	5.1	5.5	5.9	6.0	6.3	6.4	6.4	6.0
Comb. # 73																				
Contraction	0.0	—1.2	—2.6	—3.2	—4.2	—3.8	—4.0	—4.4	—3.6	—3.6	—4.4	—6.8	—8.2	—8.8	—8.4	—8.0	—7.8	—8.2	—8.0	—7.8

Training combinations 1, 2, 3—8 Ss contraction, 8 Ss dilation.
Training combination 4—7 Ss contraction, 8 Ss dilation.
Training combinations, 5, 6, ...10, ...20,—5 Ss contraction, 5 Ss dilation.
Training combination 73—1 S contraction, 0 Ss dilation.

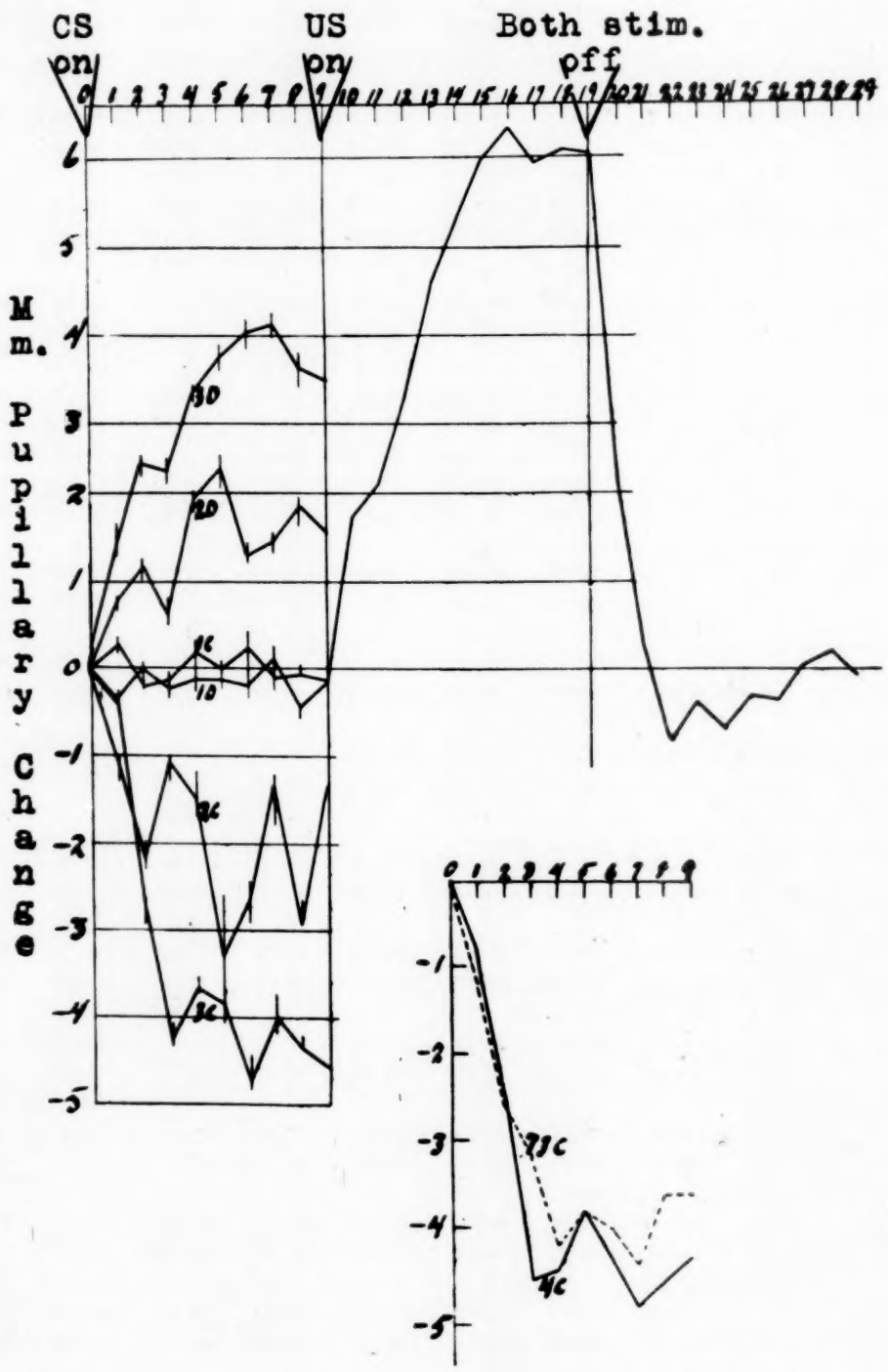

FIG. 2. Successive training combinations, showing changes in anticipatory response in course of conditioning.

1D—Training combination No. 1—conditioned dilation.
2D— " " No. 2— " "
3D— " " No. 3— " "
1C, 2C, 3C, 4C, and 73C—Training combinations 1, 2, 3, 4, and 73—conditioned constriction.

Conclusions. Such a graphical summary as is shown in Fig. 2 presents strikingly the conclusions which must be drawn from our data. These are as follows:

1. Training combination number 1 (curves 1C and 1D) shows no anticipatory response. Our data here give another control which indicates that there was no original, unconditioned response to the subliminal stimulus.

2. Training combination number 2 (curves 2C and 2D) shows an anticipatory response involving a maximum pupillary change of 2.48 mm. in the case of conditioned dilation, and a maximum pupillary change of 3.32 mm. in the case of conditioned constriction. In other words, the data here show unmistakable evidence of conditioning after a single training combination.

It is important to note, however, that this response differs from subsequent anticipatory responses both in amplitude and in form. One of the most striking characteristics of the response at this stage of the conditioning process lies in the fact that the amount of fluctuation is much greater here than either before training (as in curves 1C and 1D) or after further training (as in curves 3D, 3C, 4C, and 73C). Because of this fluctuant character of the response, we have elected to speak of it as a conditioned "disturbance." This conditioned *disturbance* response appeared in all *S*s immediately after the first training combination.

3. Training combination number 3 (curves 3C and 3D) shows an anticipatory response which has lost the unstable character of the *disturbance* response, and which is greater in amplitude and more sharply defined in form.

4. Training combination number 4 (curve 4C) shows an anticipatory response which is almost identical to that elicited in combination number 3. Furthermore, the form of the anticipatory response remains the same in all subsequent training combinations. In order to demonstrate this latter fact, we have included in Fig. 2 the response-curve of the 73rd training combination of a single *S*. Comparison of these responses shows that the anticipatory response of the 73rd is almost identical to the anticipatory response of the 3rd training combination. This similarity is even more striking when we call attention to

the fact that 3C is a composite curve from 8 *S*s, while 73C is a reproduction of the response-curve of a single *S*.

Because it is different in form and amplitude from the *disturbance* response, and because we find no further alteration of the response with further training, we have chosen to call this the *final form* conditioned response.

On the basis of these data the conclusion seems inescapable that when a pupillary response is conditioned to a subliminal auditory stimulus, the learning is accomplished in two stages. The first of these occurs after a single training combination and represents a conditioned *disturbance* of the responding modality. The second stage of the conditioning process results in the *final form* conditioned response, which is different in form and amplitude from the *disturbance* response. The *final form* response results from a single further training combination after the *disturbance* response has been conditioned and remains unaltered in form or amplitude by further training. The development of conditioning from *disturbance* to *final form* appears to be sudden and complete, rather than as a result of gradual recruitment.

SECTION VI. COMPARISON OF CONDITIONING TO SUPRA- AND TO SUBLIMINAL STIMULI

Problem. To compare form, amplitude, and relative ease of conditioning to supra- and to subliminal stimuli.

Procedure. Session 1—Determination of the limen.

Session 2—(a) Checking of the limen. (b) One of the following procedures was used for each *S*. It will be noted that the two procedures reverse the order of periods in order to control any effect of that factor on the results.

Group A	Group B
1. *Test-sub-2.*	1. *Test-supra.*
2. *Test-supra-.*	2. *Test-sub-2.*
3. *Train-sub-2* (constriction).	3. *Train-supra* (constriction).
4. *Test-supra-.*	4. *Test-sub-2.*
5. *Test-sub-2.*	5. *Test-supra-.*
6. *Train-supra* (dilation).	6. *Train-sub-2* (dilation).
7. *Test-sub-2.*	7. *Test-supra-.*
8. *Test-supra-.*	8. *Test-sub-2.*

Eight *S*s were used in the above procedures, four with procedure A, and 4 with procedure B. The procedures were so devised as to have each *S* give opposite conditioned responses to the two *CS* intensities, *sub-2,* and supra-. Thus, an *S* who had been conditioned to give a pupillary contraction as a response to a subliminal stimulus was later trained to give a pupillary dilation to a stimulus of supraliminal intensity. The supraliminal intensities used were the loudest that could be administered with our audiometer. That these intensities were not very great is attested by the fact that some *S*s had initial difficulty in discriminating out this sound as compared with the low hum of the audiometer motor and the click of the Harvard clock.

Results. The results of this procedure are given in Table III. The horizontal rows of this table give the data in the following order: (1) the response conditioned, (2) the intensity of *CS,* (3) the particular *S* used, (4) the number of training combinations given before the conditioned *disturbance* response was elicited, and (5) the number of training combinations given before the appearance of the *final form* response. Thus, for instance, it may be seen that subject B took one training combination to produce the conditioned *disturbance* response and two

TABLE III

RELATIVE EASE OF CONDITIONING TO SUPRA- AND SUBLIMINAL SOUNDS

Conditioned response	CS intensity	S	No. Trg. Combs. to Produce *Disturbance*	No. Trg. Combs. to Produce *Final Form*
Dilation	Sub.-2	A	1	2
Dilation	Sub.-2	B	1	2
Dilation	Sub.-2	C	1	2
Dilation	Sub.-2	D	1	2
Contraction	Sub.-2	E	1	2
Contraction	Sub.-2	F	1	2
Contraction	Sub.-2	G	1	2
Contraction	Sub.-2	H	1	2
Dilation	Supra	E	48	49
Dilation	Supra	F	56	57
Dilation	Supra	G	74	78
Dilation	Supra	H	103	105
Contraction	Supra	A	28	29
Contraction	Supra	B	59	61
Contraction	Supra	C	74	75
Contraction	Supra	D	37	44

to produce the *final form* in the training of conditioned dilation to a subliminal stimulus. Similarly, the same *S* required 59 and 61 training combinations before the *disturbance* and *final form* responses, respectively, were conditioned to a supraliminal stimulus. In this procedure, as in previous ones, the two stages of conditioning were easily identifiable on the basis of form and amplitude.

Conclusions. While the results in Table III for subliminal conditioning agree exactly with those shown in earlier sections of this paper, a marked difference in ease of conditioning is noted when supraliminal intensities of *CS* were used. In the case of subliminal intensities the conditioned response was uniformly easy to establish. When *CS* was supraliminal, however, a greater number of training combinations was necessary to establish the connection. The quickest conditioned *disturbance* response to a supraliminal stimulus occurred in 28 training combinations, while the same *S* (subject A) had given the response after only one training combination with a subliminal *CS*.

A further important difference shown by this table is that there are here manifested, for the first time, individual differences in the ease of conditioning. The range of number of training combinations necessary to produce conditioned *disturbance* responses to a supraliminal stimulus was from 28 to 103. The same response was uniformly conditioned to a subliminal stimulus in only one training combination. Furthermore, the number of additional training combinations necessary to achieve the *final form* response varied from 1 to 7 when *CS* was supraliminal, while this change was also uniformly achieved in only one training combination with a subliminal *CS*.

As in the case of conditioning to a subliminal *CS*, conditioning to a supraliminal stimulus intensity was also marked by a certain suddenness of appearance. In 4 out of the 8 *S*s, the *final form* response appeared on the next combination after the first appearance of the *disturbance* response. Those cases in which more than one training combination intervened were characterized in every instance by a persistence of the *disturbance* response throughout the intervening combinations.

SECTION VII. SPECIFICITY AND LOWER LIMITS OF CONDITIONED STIMULUS INTENSITY

Problem. To test the specificity of the conditioned connection, and to find the lower limit of conditionability.

Procedure. Session 1—Determination of the limen.

Session 2—(a) Checking of the limen. (b) One of the two following procedures was used.

Procedure A.

1. *Train*
   - Subject A—*sub-2.*
   - Subject B—*sub-3.*
   - Subject C—*sub-4.*
   - Subject D—*sub-5.*
   - Subject E—*sub-6.*
   - Subject F—*supra-5.*
2. *Test-sub-13.*
3. *Test-at-trained-intensity.*
4. *Test-sub-11.*
5. *Test-at-trained-intensity.*
6. *Test-sub-9.*
7. *Test-at-trained-intensity.*
8. *Test-sub-7.*
9. *Test-at-trained-intensity.*
10. *Test-sub-5.*
11. *Test-at-trained-intensity.*
12. *Test-sub-4.*
13. *Test-at-trained-intensity.*
14. *Test-sub-3.*
15. *Test-at-trained-intensity.*
16. *Test-sub-2.*
17. *Test-at-trained-intensity.*
18. *Test-supra-5.*
19. *Test-at-trained-intensity.*
20. *Test-supra-4.*
21. *Test-at-trained-intensity.*
22. *Test-supra-3.*
23. *Test-at-trained-intensity.*
24. *Test-supra-2.*
25. *Test-at-trained-intensity.*
26. *Test-supra-1.*
27. *Test-at-trained-intensity.*
28. *Test-at-limen.*
29. *Test-at-trained-intensity.*
30. *Test-sub-1.*
31. *Test-at-trained-intensity.*

Procedure A, in which 6 *S*s were used, was devised to test the lower limit of conditionability and to give data on the specificity of the conditioned connection. Training was continued either until the *final form* response was elicited or until 150 training combinations failed to elicit the response. In case conditioning did not occur, the rest of the procedure was abandoned. Only one test trial was made at each of the points indicated in the outline, and in this manner we explored almost the entire intensity-range of our audiometer. It will be noted that tests at the trained *CS* intensity were interspersed between all other tests. The purpose of this was to show whether we were really operating beyond the range of specificity of the response in those cases where there was a response-failure, or whether we had merely extinguished the conditioned connection.

TABLE IV

SPECIFICITY OF CONDITIONED CONNECTION AND LOWER LIMIT OF CONDITIONABILITY

Procedure A

Response	Subject	Stimulus intensity	No. trg. comb.	Responses at various intensities of sound (x indicates trained intensity)									
				—5	—4	—3	—2	—1	x	1	2	3	4
Contraction	A	Sub-2.	2	0	0	0	0	0	F.F	F.F	0	0	0
Contraction	B	Sub-3.	2	0	0	0	0	0	F.F	0	0	0	0
Contraction	C	Sub-4.	2	0	0	0	0	0	F.F	D.	0	0	0
Contraction	D	Sub-5.	150	0	0	0	0	0	0	0	0	0	0
Contraction	E	Sub-6.	150	0	0	0	0	0	0	0	0	0	0
Contraction	F	Supra-5	82	0	0	0	0	D.	F.F	D.	D.	0	0
			Procedure B										
Contraction	R.S.	Sub-2.	3	0	0	0	0	D.	F.F	0	0	0	0
Contraction	R.Z.	Sub-2.	3	0	0	0	0	D.	F.F	D.	D.	0	0
Dilation	M.M.	Sub-2.	3	0	0	0	0	0	F.F	0	0	0	0
Dilation	J.S.	Sub-2.	3	0	0	0	D.	0	F.F	0	0	0	0

D.=*Disturbance* response.
F.F=*Final form* response.
0=No response.

No. trg. comb.=number of training combinations given.
—5, —4, —3, —1=number of audiometer units *below* trained intensity.
1, 2, 3, 4=number of audiometer units *above* trained intensity.

Procedure B. Four *S*s were used in the procedures outlined below. Subjects R.S. and R.Z. were trained to give conditioned contractions, while subjects M.M. and J.S. were trained to give conditioned dilations.

1. *Train-sub-2.*—3 training combinations.

2. *Test-sub-2., sub-3., sub-4.,* and *sub-5.,* interspersing tests at trained intensity.

3. *Test-sub-1., at limen, supra-1., supra-2., supra-3.,* and *supra-4.* in same manner as 2., above.

This procedure was designed to give additional data on the specificity of the connection, with *CS* intensity and number of training combinations held constant.

Results. The results of these two procedures are summarized in Table IV. In this table each row gives (1) the response conditioned, (2) the *S* involved, (3) the stimulus intensity at which training occurred, and (4) the number of training combinations given to the particular *S* of that row. These data occupy the first four columns of the table. In the next columns are tabulated the responses which occurred 5, 4, 3, 2, and 1 audiometer units below, and 1, 2, 3, and 4 audiometer units above the stimulus intensity at which the training occurred. The responses which occurred at the trained intensity are shown in column x. This column (column x) records the results of between 5 and 15 tests in each cell because of the fact that tests at the trained intensity were interspersed between all other tests and were therefore more numerous. All other columns in this section of the table contain the data for a single test in each cell. On one of the interspersed tests at the trained *CS* intensity of subject B, a *disturbance* response occurred at the trained intensity. In all other cases in which conditioning was successfully established, the *final form* response was invariably present at the trained intensity. Thus, for instance, the table shows that subject A, who was given 2 training combinations in the direction of contraction, with a *CS* intensity of *Sub-2.,* gave the *final form* response both at this intensity and one unit above this intensity. This *S* gave no responses at other intensities, and the conditioned

connection may be said to have been specific to those two intensities of *CS*. Similarly, subject R.S. gave a *disturbance* response to *CS* one unit below the specific intensity at which training had occurred. This *S* gave the *final form* response at the specific trained intensity (*Sub-2.*) and no conditioned responses at other intensities.

Conclusions. The results as tabulated support the following conclusions:

(1) The conditioned pupillary response is specific to a very high degree, since there is not generalization beyond four audiometer units (or somewhat less than 4 j.n.d's.).

(2) The *disturbance* response is less specific than the *final form* response.

(3) Both *final form* and *disturbance* responses may exist at the same time in the same subject. This fact is shown by the occurrence of *final form* responses at the specific trained intensity and *disturbance* responses at adjacent intensities in the same *S*.

(4) There is some evidence that conditioned pupillary responses to subliminal stimuli are more specific than to supraliminal stimuli. This conclusion is indicated by the fact that the responses of subject F. were less specific than those of all but one other *S*, in spite of the fact that he had received 82 training combinations as compared with 2 or 3 for all the other subjects.

(5) The range of subliminal stimuli to which it is possible to condition pupillary responses is quite small. This is indicated by the fact that no conditioned responses appeared, even after 150 training combinations, to stimuli that were more than four audiometer-units below the conscious threshold. This range compares quite favorably with the range of intensities in which subliminal auditory stimuli may have an effect upon verbal behavior (1).

(6) There is no evidence that ease of conditioning is a function of the intensity of *CS* within this range.

SECTION VIII. EXPERIMENTAL EXTINCTION

Problem. To investigate experimental extinction of the pupillary response conditioned to supra- and to subliminal auditory stimuli.

Procedure. Systematic attempts were made with all *S*s to induce experimental extinction of the conditioned responses. The method used was to give unreinforced presentations of *CS* while giving frequent rests and making frequent inquiries as to *S*'s state of fatigue, feelings, etc. A total of 34 *S*s were studied in this manner. Of these, 8 had been conditioned to both supra- and to subliminal stimuli (opposite responses having been conditioned to the two intensities in each *S*) and one had been conditioned only to a supraliminal intensity. All others (25) had been conditioned only to subliminal intensities.

The mean number of unreinforced presentations of *CS* was 152±9.4, while the minimum number given was 86.

Results. In no case was experimental extinction observed either as regards the form or the amplitude of the response.

In a single case, in which unreinforced presentations were given with little regard for fatigue of *S*, the character of the response changed to *disturbance* after 143 presentations. The *disturbance* form continued to be given for 8 further presentations, and on the 152nd presentation, no conditioned response occurred. There were no further conditioned responses elicited in 8 further presentations of *CS*, with the exception of a *final form* response which occurred at the 156th.

After the 160th presentation, 2 hrs. and 18 min. after the beginning of the session, *S* complained of fatigue and bladder tension and asked to be allowed to go to the toilet. Upon his return the *final form* response was immediately elicited and continued to appear without exception on the 20 presentations of the remainder of the testing session. On the following day the same *S* was given 130 further unreinforced test presentations interrupted by rests between every 2. The response showed absolutely no decrement or change of form.

The same *S* was one of four tested for retention after a long lapse of time, and the *final form* response was found still to persist 413 days later.

Conclusions. It is immediately apparent that the response-decrement which we obtained in a single case, and which we had at first thought to be the result of experimental extinction was in reality a case of so-called "external inhibition." In all the rest of our data we found no other case of a decrement in the conditioned response as a result of unreinforced presentations of *CS*.

SECTION IX. UNCONDITIONING

Problem. To investigate the course of unconditioning by means of reconditioning in the opposite direction.

Procedure. Four *S*s were used in the procedures outlined below:

(A) Subjects R.S. and R.Z.

1. *Train* (constriction) *Sub-2.* (3 training combinations.)
2. *Test Sub-2.* (1 test presentation.)
3. *Train* (dilation) *Sub-2.*

(B) Subjects M.M. and J.S.

1. *Train* (dilation) *Sub-2.* (3 training combinations.)
2. *Test Sub-2.* (1 test presentation.)
3. *Train* (constriction) *Sub-2.*

Results. The results of this procedure are given in Table V, and Fig. 3 is a graphical presentation of two of the four cases. Both the table and the figure include only the delay period, in which the anticipatory response occurred. The table shows (1) the particular *S* involved in each section, (2) the response first conditioned, (3) the new direction of training, and (4) the height of the response-curve in successive seconds of the delay period. The figure is simply a graphical presentation of the same data and shows two series of anticipatory responses in which *S*s, originally conditioned to give *final form* responses in one direction, were then conditioned to give the same form of response in the opposite direction.

TABLE V

ANTICIPATORY RESPONSES IN UNCONDITIONING

Subject and trg. comb. number	Response first conditioned	New direction of conditioning	Pupillary change in mm. during successive seconds of delay period									
			0	1	2	3	4	5	6	7	8	9
R.S. # 1	contraction	dilation	0.0	0.8	—3.0	—5.0	—5.0	—5.4	—6.6	—7.4	—6.6	—7.6
# 2		"	0.0	1.0	—3.0	—4.0	—4.0	—4.8	—4.4	—5.0	—2.4	—3.8
# 3		"	0.0	—1.6	—3.6	—4.0	—4.0	—4.0	—2.2	—5.2	—4.0	—4.6
# 4		"	0.0	1.6	—2.0	—2.2	—4.6	—5.0	—2.4	—4.0	—2.6	—4.6
# 5		"	0.0	—1.2	—1.8	0.4	—1.2	0.0	1.2	2.4	0.2	0.0
# 6		"	0.0	0.4	2.4	4.0	1.2	—0.4	4.0	1.6	—0.4	4.4
# 7		"	0.0	2.6	0.4	4.2	5.4	4.2	3.0	4.0	6.0	4.2
# 8		"	0.0	1.2	2.6	4.6	4.0	6.0	4.4	5.6	5.4	4.0
J.S. # 1	dilation	contraction	0.0	1.4	3.2	3.6	5.0	5.2	4.4	5.0	5.0	4.8
# 2		"	0.0	1.2	2.0	3.0	4.4	5.6	3.8	4.6	4.8	4.8
# 3		"	0.0	0.4	2.8	4.4	4.4	3.4	5.2	5.6	5.0	5.2
# 4		"	0.0	1.2	—0.6	4.0	4.4	5.0	5.6	5.4	5.4	0.8
# 5		"	0.0	2.0	4.0	4.4	4.2	3.2	4.8	5.0	4.4	4.0
# 6		"	0.0	0.0	1.2	2.4	1.0	3.6	3.4	3.6	4.6	3.8
# 7		"	0.0	0.0	0.6	1.8	2.8	3.2	2.0	3.0	3.2	1.2
# 8		"	0.0	1.2	1.2	2.2	0.2	1.6	1.8	0.4	1.2	2.0
# 9		"	0.0	—1.0	0.4	3.0	1.4	—0.2	3.0	1.8	2.8	2.4
# 10		"	0.0	—1.0	0.0	1.6	1.6	2.4	1.2	3.2	2.0	3.8
# 11		"	0.0	—1.0	2.2	—2.4	2.2	1.0	2.4	1.4	2.6	2.2
# 12		"	0.0	2.2	0.0	2.0	3.0	—1.0	—2.2	2.2	3.2	2.4
# 13		"	0.0	0.4	2.4	0.2	—2.0	—2.4	—2.4	2.2	0.0	3.6
# 14		"	0.0	—0.6	3.0	—0.2	0.0	3.2	1.0	2.8	0.0	1.0
# 15		"	0.0	0.4	—1.0	—1.4	0.4	1.6	—1.0	—2.4	1.4	0.6
# 16		"	0.0	1.0	—1.4	2.6	—1.2	—2.4	—0.4	—2.2	0.0	—1.0
# 17		"	0.0	1.4	—3.6	0.8	—3.8	0.2	—1.4	—0.4	—1.6	—3.8
# 18		"	0.0	—2.2	—2.8	—4.8	—4.4	—4.8	—4.6	—4.6	—3.8	—4.0

TABLE V—*Continued*

Subject and trg. comb. number	Response first conditioned	New direction of conditioning	Pupillary change in mm. during successive seconds of delay period									
			0	1	2	3	4	5	6	7	8	9
R.Z. # 1	contraction	dilation	0.0	—1.2	—2.2	—3.8	—3.8	—3.8	—4.8	—3.8	—5.2	—5.0
# 2		"	0.0	—1.4	—2.8	—3.6	—3.8	—4.6	—4.0	—4.6	—5.0	—4.2
# 3		"	0.0	—1.0	—2.2	—3.0	—2.8	—4.0	—4.6	—4.0	—3.8	—4.4
# 4		"	0.0	—0.2	0.0	—1.2	—2.6	—3.4	—4.4	—3.0	—4.6	—4.0
# 5		"	0.0	0.8	0.0	—1.6	—2.8	—3.2	—4.8	—3.2	—5.2	—3.8
# 6		"	0.0	1.2	0.8	—2.4	—3.6	—4.2	—4.0	—4.4	—4.0	—0.6
# 7		"	0.0	1.0	1.4	—1.6	—2.4	—0.4	0.6	1.2	—1.6	—2.8
# 8		"	0.0	1.2	2.6	4.4	0.0	—2.2	—3.2	0.8	—0.8	—2.4
# 9		"	0.0	0.0	—1.8	—2.6	0.6	3.0	1.8	—0.6	—3.6	—4.0
# 10		"	0.0	0.0	—1.2	3.4	4.0	0.2	—0.8	—1.8	0.6	2.2
# 11		"	0.0	0.6	1.4	2.6	3.2	0.4	1.2	—0.2	1.8	3.2
# 12		"	0.0	1.8	3.2	4.6	3.8	0.6	4.0	4.4	3.8	4.2
# 13		"	0.0	1.2	3.6	4.0	4.4	4.0	4.8	4.2	4.6	4.8
M.M. # 1	dilation	contraction	0.0	0.4	5.0	5.2	3.4	3.8	3.6	4.0	3.6	3.8
# 2		"	0.0	3.0	3.2	0.6	3.0	4.6	5.0	4.2	4.0	4.4
# 3		"	0.0	1.0	0.4	3.4	4.0	4.0	3.6	4.2	4.2	4.6
# 4		"	0.0	—0.4	1.6	2.4	3.4	4.2	4.4	3.8	4.0	4.0
# 5		"	0.0	—0.8	0.6	—0.4	1.8	2.6	3.8	4.8	3.6	3.2
# 6		"	0.0	—0.8	1.4	3.8	0.6	2.2	3.6	4.0	3.8	3.8
# 7		"	0.0	0.2	2.8	—1.6	—2.4	1.0	2.4	—0.8	—0.2	1.6
# 8		"	0.0	1.2	—1.6	—0.4	1.4	2.4	—0.8	—2.2	—0.2	—1.0
# 9		"	0.0	—0.6	—2.0	—3.2	—0.2	—1.6	—2.2	0.0	0.2	—1.4
# 10		"	0.0	—1.2	—2.6	—4.0	—0.4	—0.2	—2.4	—4.6	—4.4	—4.2
# 11		"	0.0	—1.4	—2.8	—3.6	—4.8	—4.4	—4.6	—4.0	—4.2	—4.0

Conclusions. These results justify the following conclusions:

(1) There are individual differences in ease of unconditioning when the stimulus is subliminal. Note, for instance, that J.S. took 18 training combinations to arrive at the new *final form* response, R.Z. took 13, M.M. took 11, and R.S. took 8.

(2) There is evidence that the *disturbance* response may have a directional character that is positive, negative, or neutral, and still remain different in form from the *final form* response. In the case of J.S. in Fig. 3, for instance, the responses shown in curves A and B (the first, second, and fourth training combinations) are *final form* responses. The responses shown in curves C, D, E, F, and H (training combinations 6, 8, 10, 12, and 14) are typical *disturbance* responses, but show a predominant tendency toward dilation. Curve I (training combination 16) shows a *disturbance* response with no single directional tendency, while curve J (training combination number 17) shows a *disturbance* response with a predominant tendency in the direction of constriction. Curve K for this *S* (showing the anticipatory response on the eighteenth training combination) is a *final form* response in the direction of constriction. The same stages may be observed in the course of unconditioning of subject R.S., shown in the same figure. These conclusions are also indicated by the data from the two *S*s not shown in this figure whose unconditioning data are given in Table V.

It is significant to note that if these responses were treated only in terms of amplitude, the picture would be one of gradual increments and decrements and these differences in form of the response would be obscured.

(3) All *S*s again showed the abrupt transition from *disturbance* to *final form* response which has been shown in other procedures.

SECTION X. RETENTION

Problem. To study the possibility of long-time retention of the conditioned pupillary response.

Procedure. We were able to get four *S*s to return for a retest

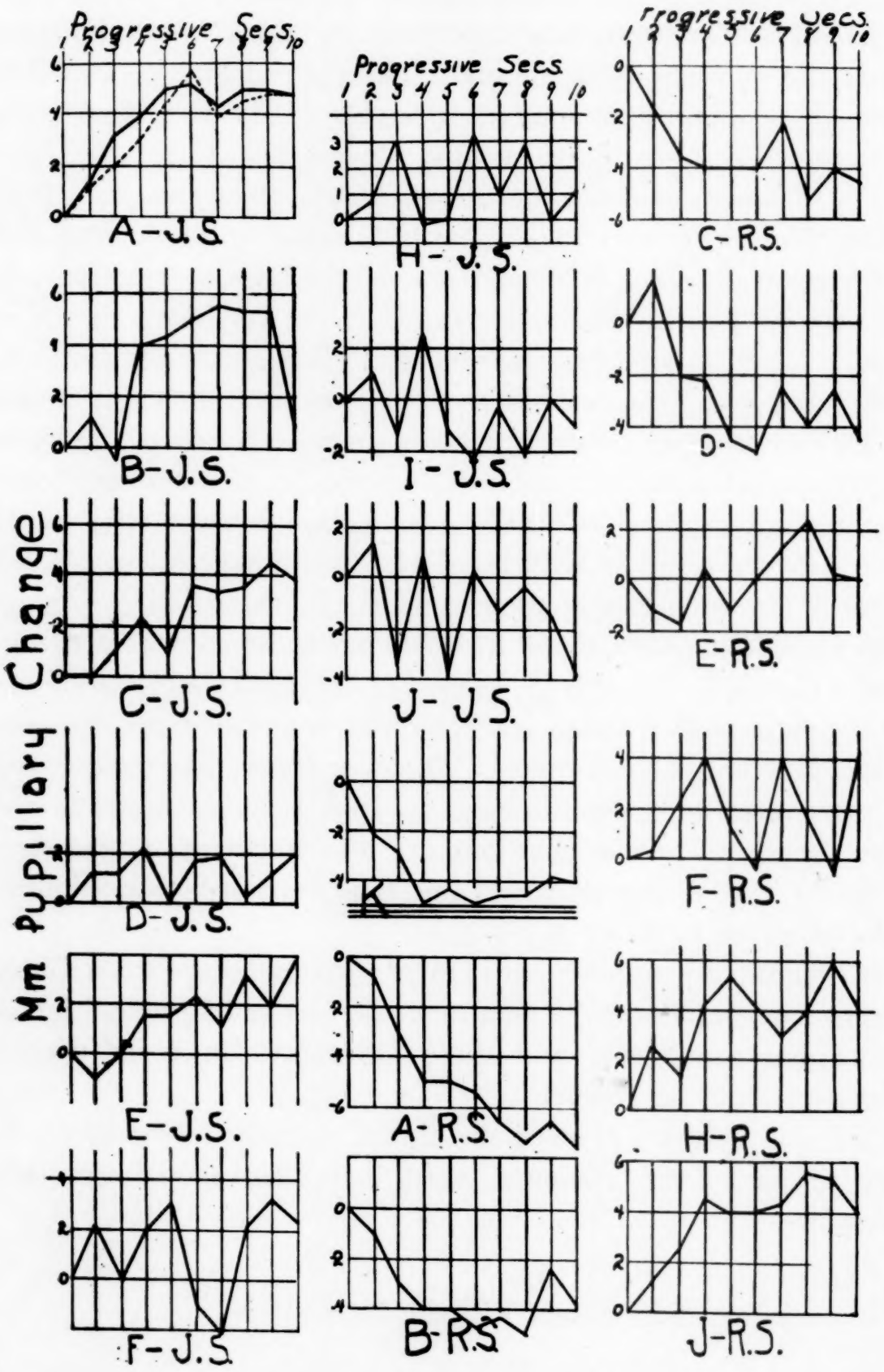
Progressive Secs
A-J.S.
H-J.S.
C-R.S.
B-J.S.
I-J.S.
D-
C-J.S.
J-J.S.
E-R.S.
Change
D-J.S.
F-R.S.
Mm Pupillary
E-J.S.
A-R.S.
H-R.S.
F-J.S.
B-R.S.
J-R.S.

FIG. 3

after the lapse of 18 to 20 months time. These four were given further unreinforced presentations of *CS*.

Results. The results of these tests for each of the four *S*s are indicated in Table VI.

TABLE VI

RETENTION

Subject	*CS* intensity	Response conditioned	Time of retention period	Test result
R.L.	Sub-2	Contraction	14 mo., 12 da.	*Final form*
R.L.	Supra-	Dilation	14 mo., 11 da.	No response
M.S.	Sub-2	Contraction	16 mo., 21 da.	*Final form*
M.S.	Supra-	Dilation	16 mo., 14 da.	*Final form*
M.W.	Sub-2	Dilation	20 mo., 3 da.	*Final form*
M.W.	Supra-	Contraction	20 mo., 2 da.	*Disturbance*
W.B.	Sub-2	Contraction	13 mo., 16 da.	*Final form*

Conclusions. It is clear that this response exhibits a marked stability as regards retention. Our results here, as well as in the case of experimental extinction, indicate that the conditioned pupillary response is not the unstable thing that Pavlov's description makes of the conditioned salivary response in dogs. We feel that the following conclusions are tentatively suggested by these data:

(1) The retention is better when *CS* is subliminal. This conclusion is indicated by the fact that two *S*s showed a decrement

FIG. 3 (opposite page). Successive training combinations, showing changes in anticipatory response in course of unconditioning in two *S*s.

A—J.S. (solid line)—Training combination No. 1, subject J.S. Conditioned dilation is present and unconditioning is proceeding by the training of constriction.
A—J.S. (dotted line)—Training combination No. 2, subject J.S.
B—J.S.—Training combination No. 4, subject J.S.
C—J.S. " " No. 6, " "
D—J.S. " " No. 8, " "
E—J.S. " " No. 10, " "
F—J.S. " " No. 12, " "
H—J.S. " " No. 14, " "
I—J.S. " " No. 16, " "
J—J.S. " " No. 17, " "
K— " " No. 18, " "

A—R.S.—Training combination No. 1, subject R.S. Conditioned constriction is present and unconditioning is proceeding by the training of dilation.
B—R.S., C—R.S., D—R.S., E—R.S., F—R.S., H—R.S., and J—R.S.—Training combinations Nos. 2, 3, 4, 5, 6, 7, and 8, subject R.S.

in responses conditioned to supraliminal stimuli, while none showed any decrement of responses conditioned to subliminal intensities.

(2) The *disturbance* response may persist after the *final form* response has been lost, as in the case of subject M.W. in Table VI.

SECTION XI. DISCUSSION

The disturbance response. In discussing the implications of our data we wish first to call attention to four important facts: (a) The conditioned *disturbance* response appeared as an initial stage of conditioning, and was superseded by the *final form* response. (b) The *final form* response appeared on stimulation at the trained intensity, but at adjacent intensities of *CS* the conditioned *disturbance* response appeared. (c) In the single case of external inhibition a residual conditioned *disturbance* response was found to remain after the *final form* response had disappeared. (d) In the case of unconditioning there was also a residual *disturbance* response after the disappearance of the *final form* response.

All of these data are a part of the description of the *disturbance* response, and seem to indicate that it may be thought of as remaining as a basis for the later *final form* response. In other words, the bodily pattern involved in the conditioned *disturbance* response may be thought of as an implicit component of the conditioned *final form* response.

Furthermore, since the *disturbance* response itself appears in three characteristic forms in unconditioning, we may analyze it into three sub-groups. If we name these in relation to the direction of the unconditioned response, they may be called, in the order of their appearance in unconditioning: (a) *Negative disturbance*—a *disturbance* response with tendency in a direction opposite to that of the unconditioned response. (b) *Neutral disturbance*—a *disturbance* response with no directional tendency. (c) *Positive disturbance*—a *disturbance* response with tendency in the same direction as that of the unconditioned response. Of these, it is the *positive disturbance* which appears

as the first stage of conditioning in our data. Our data do not indicate whether or not the others ever occur except in the unconditioning procedure.

There is some evidence in our data that the course of conditioning to supraliminal stimuli presents the same development through *disturbance* to *final form* response, but that this basic picture is obscured by the intervention of such uncontrollable factors as attention, etc., which are introduced by conscious processes. Other studies of the course of acquisition of the conditioned response with a supraliminal *CS* have usually consisted merely in descriptions of the change in amplitude of the response. If we analyze such data, however, we often find that the gradual increment which is the statistical expression of the course of the conditioning process is based on cases which, taken individually, are typified by aberrance as regards the measures of central tendency. The data of Hilgard and Campbell (**10**) for example, show a variability during the acquisition of the response which is about four times as great as after conditioning has been established. We believe that the forms of conditioned response which we have described may be at the basis of the types of conditioned eye-lid responses reported by Bernstein (**2**) and by Hilgard and Campbell (**10**).

General principles. We conceive the conditioning of non-conscious responses to non-conscious stimuli to be a case of learning which is not mediated by all the variable and uncontrollable factors involved in conscious learning. It follows from this conception that one may hope to infer from such conditioning principles which are basic to all learning. The first such general principle of conditioning on the basis of our data must then be that *a single training combination is sufficient to form a functional connection* of such a nature that *CS* causes a diffuse "tendency to react" in the effector as a whole. This principle combines Guthrie's (**7**) description of conditioning in one training combination with Culler's (**5**) suggestion that there is initially only a tendency to react. This principle gains credibility from the fact that responses usually reported as conditioned in one or a few training combinations are those, such as emotional behavior, which are characterized by a mere formless "tendency

to respond" rather than by sharply defined and predictable behavior.

The second general principle possible of derivation from our data would state that *training combinations after the first cause a reduction of variability in the S-R connection* so as to produce behavior with a single directional tendency. This principle is indicated by the data which show that the *disturbance* response gives way with further training to the *final form* response, and by the fact that the data of other experimenters (see Bernstein and Hilgard and Campbell) are susceptible to the same interpretation.

The third general principle is that *S-R connections which are mediated by conscious processes are not predictable on the basis of what happens when conscious processes are not involved.* The introduction of such factors as perception, attention, judgment, verbalization, "insight," etc., presents a new emergent for which new laws of learning will operate and for which "lower level" principles may or may not predict adequately. As a corollary to this principle, one would expect that there would be greater variability in behavior when *CS* is supraliminal than when it is subliminal. This expectation is adequately borne out by the data which show the response uniformly conditioned in the first and second training combinations with a subliminal *CS*, but requiring a varying number of combinations when *CS* was supraliminal. We believe that it is this corollary that explains the otherwise heretical finding that it is easier to establish conditioning to subliminal than to supraliminal stimuli. The obvious implication here is that the conditioning is easier because the possible variables which would operate to make conditioning difficult (*i.e.*, obscure and distort it) have been controlled by the single expedient of excluding them.

SECTION XII. SUMMARY AND CONCLUSIONS

In this experiment an attempt was made to condition a pupillary response, by means of the delayed conditioning method, to an auditory stimulus of so low an intensity as to be below the conscious judgment threshold of the subject. A total of 34 human

subjects was used in seven different experiments. These experiments investigated the following problems: (a) the conditioning of the response, (b) the course of conditioning, (c) comparison of conditioning to supra- and to subliminal stimuli, (d) specificity and lower limits of conditioning stimulus intensity, (e) experimental extinction, (f) unconditioning, and (g) retention. The results of the study justify the following conclusions:

1. The pupillary response can be conditioned to a subliminal auditory stimulus.

2. The conditioning is accomplished in two stages. The first of these results from a single training combination and is typically merely a "disturbance" of the responding modality. We have called this the conditioned *disturbance* response. The second stage results from a single further training combination and, since further training combinations do not cause further alterations of this response, we have chosen to call it the *final form* response.

3. The conditioned connection is more easily established when the conditioned stimulus is subliminal than when it is supraliminal.

4. There is some evidence that conditioned responses to subliminal stimuli are more specific than to supraliminal stimuli.

5. The conditioned pupillary response is specific to a high degree.

6. The *disturbance* response is less specific than the *final form* response.

7. There is evidence that the conditioned response goes through the same stages when the conditioned stimulus is supraliminal that it does when the conditioned stimulus is subliminal.

8. The conditioned *final form* response may be thought of as having the conditioned *disturbance* response as an implicit component.

9. There are few or no differences in ease of conditioning when the conditioned stimulus is subliminal, but when it is supraliminal large differences appear.

10. The conditioned *disturbance* response may be further analyzed by unconditioning into responses that progress from

negative, through neutral, to positive directional tendencies as oriented against the direction of the unconditioned response.

11. There are individual differences in the ease of unconditioning when the conditioned stimulus is subliminal.

12. Experimental extinction does not occur, but one case is reported which exhibited external inhibition.

13. There may be little or no loss suffered by the conditioned response over a retention period of from 13 to 20 months.

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